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KHALED NASRI, HOUDA BOUBAKER AND NACEF DHAOUADI

SUSTAINABLE DEVELOPMENT GOALS
AND EXTERNAL SHOCKS IN THE MENA REGION:

FROM RESILIENCE TO CHANGE IN THE WAKE OF COVID-19

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Dynamic Governance of the First Wave of Covid-19 in Tunisia: An Interoperability Analysis

Khaled Nasri[1]
FESGT, University of Tunis EL Manar, Tunisia
Houda Boubaker
FESGT, University of Tunis EL Manar, Tunisia
Nacef Dhaouadi
FESGT, University of Tunis EL Manar, Tunisia

Abstract:

This paper aims to propose an interoperability index of the measures taken and adjusted by the Tunisian government during the first wave of coronavirus Covid-19. The concept of interoperability is defined in this research as the ability of measures, public policies or programs having common interests or objectives to be achieved, to operate together. In the first part of this research, we intend to present the process of making decision as a revised and adjusted process in continuous upgrading, based on the dynamic governance process in times of crisis. In the second part, we estimate an Index that records the strictness of government policies in each sub-period and a degree of interoperability between the Tunisian pandemic responses against covid-19 using the sub-periods instantiations. Our empirical findings show that pandemic management strategy in Tunisia, during the first wave of Covid-19, has been adjusted by adding new pandemic policies and changing the stringency levels over time. After estimating the interoperability index, we found that the measures taken early in a sub-period interact directly with the next successive sub-period in the decision process, but they interact indirectly with other successive sub-periods. Furthermore, there is clear evidence that Pandemic crisis cannot be managed or defeated with one single measure or policy even through a highest stringency level. but it was managed with several policy responses which inter-react together overtime.

Keywords: Coronavirus Covid-19, Interoperability Index, Pandemic Policies, Tunisia
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[1] Email address: kholina86@yahoo.fr , telephone number: +21692442519

1- Introduction

Since 2019, the world has been gripped by a new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and later named as Coronavirus Disease-19 (COVID-19) (Qiu et al., 2020). After being detected in the city of Wuhan in the Hubei province of China, Covid-19 has spread rapidly globally, resulting in a human tragedy and tremendous economic damage (see, For example, Baldwin and Weder di Mauro, 2020; Elgin et al., 2020; Giliberto et al (2020) and Krafft, Assaad and Marouani 2021).

It was officially declared a pandemic on March 11, 2020 by the World Health Organization, recommending range of measures and policies to be taken to manage this crisis. However, these political responses of governments cannot be uniform and they are influenced by economic, social, health, political and cultural factors of each country. Moreover, these pandemic policies are implemented and taken at different times and with varying stringency levels within a country.

On the other hand, pandemics often come in waves. In this regard, Plümper and Neumayer (2020) argue that the measures taken can powerfully reduce infection rates. They are, however, costly and tiring and therefore, typically cannot be sustained over a sufficiently long period. If fewer and fewer people follow the pandemic policies, the virus comes back and a second wave will start. Indeed, understanding how countries were able to manage the first wave of this pandemic in an uncertain and dynamic environment can provide policy makers with arguments for their decisions to manage the waves that follow. In this regard, Greer et al (2020) argue that there will be no way to understand the different responses to COVID-19 and their effects without understanding social policies to crisis management and state capacity (control over health care systems and public administration).

Tunisia like most countries in the world took some measures to prevent the entry of the virus into the country. Once the virus circulates in the country, the authorities are forced to adjust its strategy by adding the new measures or by making the application of the measures more stringent in order to decrease the rate of transmission of COVID-19 and to reduce the burden on health system. On March 22, 2020, total containment was imposed on all of Tunisia for two weeks and it was extended twice before the return to targeted containment and to a total deconfinement at June 07th 2020. However, Pandemics and crisis, cannot be managed or defeated with one single measure or policy even through a highest stringency level. they are managed with several policy responses which operate together overtime to achieve the fixed objective.

Based on the concept of dynamic governance developed by Neo and Chen (2007) and interpreted as the government's ability to continuously adjust the process in the formulation and implementation of public policies and programs that have interests to be achieved, this research focuses on quantifying the interoperability of these measures taken by the Tunisian government to manage the health crisis of covid-19. The process of making decision is described as a revised and adjusted process in continuous upgrading and can be summarized in three major types of capabilities. The first, thinking ahead- It is the capability to understand and formulate a strategy. The second, thinking again - it creates the feedback between the initial situation of the process and the new observations that allow for strategy revision and adjustment. The third, thinking across- the process is a continuous learning where the previous experience helps the current system to evolve by incorporating new ideas or concepts. The process of thinking again has proven effective in several countries such as South Korea in MERS treatment adopted in the policy formulation process in handling COVID-19 which in the process of reducing the number of spreads and deaths by looking at the health protocol that is owned accompanied by observation and analysis of the ownership of the latest data (Kim, 2020).

The rest of the paper is structured as follows. Section 2 provides an overview of COVID-19 epidemiological situation during the first wave in Tunisia and reviews the pandemic policies taken overtime. Section 3 presents our data sources and provides a detailed description of our empirical strategy. Section 4 discusses the main results, and section 5 concludes the paper.

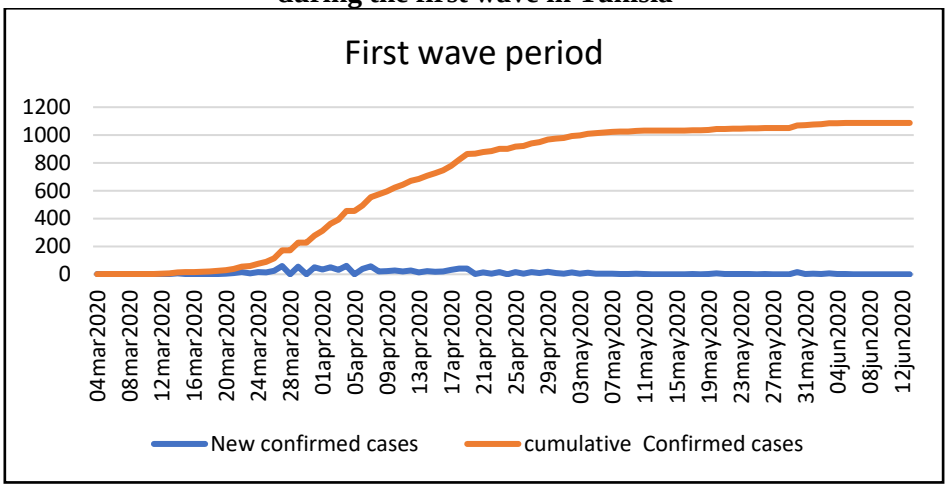
2. Background information

The first wave of covid-19 outbreak in Tunisia was lasted almost three and a half months. it was begun since the discovery of the first case in March 02, 2020 and it was extended until June 13, 2020 date of total control of the health situation, where zero new confirmed cases recorded during several successive days.

As shown in figure 1, The cumulative number of confirmed cases has increased over time, it reached 1087 cases on 05 June 2020. Given the weak capacity of the public health system in Tunisia, the major concern of the authorities is to prevent an exponential increase of the covid-19 cases, during this period. In this regard, Figures 2, 3 and 4 (see appendices) show a linear trend increase in the cumulative case curve over short periods. From 06 June, the curve became constant since the number of new cases fell to zero for several successive days. To achieve these objectives, several measures and policies have been taken and applied in a dynamic way. Since January 22, 2020, and to prevent the entry of the virus into Tunisian territory, government

has implemented early preventive measures, including screening in point of entry and systematic 14 days isolation of travelers returning from risk areas (Talmoudi et al.,2020).

Figure 1: Evolution of Cumulative confirmed covid-19 cases and Daily new confirmed cases during the first wave in Tunisia



Following the reporting of the first confirmed case, among an international traveler from Italy, on March 2, 2020, additional measures was announced and other decisions were taken to control the circulation of the virus in the country. On March 22, a national lockdown was imposed on the whole country for two weeks and it was extended twice before the return to targeted lockdown and to a total deconfinement on June 07, 2020.

As presented in table 1, the decisions were changed with the evolution of the epidemiological situation in the country. Before the imposition of total lockdown, i.e., between 04 March and 20 March, the measures taken concern the Cancel public events, Restriction on international travel, Public information campaign, Testing Policy Contact tracing, Workplace closing and School closing. All these measures are implemented with different stringency degrees or they are targeted to a specific category of individuals. On March 13, 2020, Tunisia officially enters the epidemiological phase 3. To manage the consequences of the epidemic in the best possible conditions and to mitigate their effects, some recommended measures have become mandatory and others absent before March 13 have been taken as well.

Table 1: Policy Responses during the First wave of the Sars-CoV-2 pandemic in Tunisia

Sub-Periods	Description	New Policies and Measures

P_1: [March04, March12]	Before Lockdown	- Cancel public events - Restriction on international travel - Public information campaign - Testing Policy - Contact tracing
P_2 [March13, March21]		- Workplace closing - School closing ⟹ change of stringency degree of P1 measures
P_3 [March22, April04]	Lockdown	- Restriction on gathering - Close public transport - Stay at home requirement - Restriction on internal movement - Income support - debt contract ⟹change of stringency degree of P2 policies and measures
P_4 [April05, April19]	First Extension Lockdown	-No measures added - Nothing changed
P_5 [April20, May04]	Second Extension Lockdown	
P_6 [May05, June05]	Targeted Lockdown	-No measures added ⟹Relaxing the stringency degree of P3 policies and measures
P_7 [June06, June12]	Deconfinement	- No measures added ⟹Relaxing the stringency degree of P6 policies and measures

On March 20, a lockdown was imposed on all of Tunisia. Other than the measures taken previously, new measures have been added such as restriction of collection, closure of public transport, obligation to stay at home, restriction of internal movement, income support and debt relief / contracts for households. After the registration of 61 new covid-19 cases on April 04, Tunisia extended COVID-19 lockdown twice, at the first time until 19 April and at the second time by two weeks until 4 May. From this date, the situation becomes more stable and a targeted

lockdown was announced from May 5 until June 6. This period was characterized by a change in the stringency degree and the partial removal of certain measures. the Deconfinement period in this research is officially corresponds to the third phase of targeted lockdown in Tunisia. This period is characterized by zero number of new cases for several successive days and the end of most political measures taken in previous periods against the spread of the coronavirus.

3. Data and Methodology

3.1 Data

To construct a database of policy measures taken by Tunisia in response to the covid-19 pandemic during the first wave, we used information provided by Oxford COVID-19 Government Response Tracker (OxCGRT) (Hale et al., 2020).

The OxCGRT database systematically collects publicly available information on several different common policy responses that more than 180 countries, including Tunisia, have taken to respond to the pandemic. Policy responses are classified in OxCGRT into three categories. The first category includes containment and closure policies, such as, School closing; Work place closing; Cancel public events; Restrictions on gatherings; stay at home requirements; restrictions on internal movement and International travel controls. The second category concerns economic policies such as, income support for households; Debt/contract relief for households; Fiscal measures and International support. However, Health system policies are grouped into the third category which provides information about Public information campaigns; Testing policy; Contact tracing; Emergency investment in health care and investment in vaccines (Hale et al., 2020).

To improve validity and Timeline of these information, we cross-checked this information using the CoronaNet dataset based on the daily bulletins of National Observatory of New and Emerging Diseases (ONMNE) in Tunisia. The CoronaNet Research Project compiles a database on government responses to the coronavirus. The main focus of this project is to collect much information about the various fine-grained actions governments are taking to address the effects of the COVID-19 pandemic (Cheng et al., 2020).

Based on CoronaNet data, we were able to identify the most important dates of the epidemiological situation in the country through the types of policies taken on these dates. These policies give us indications on the evolution of the decision-maker's reaction Politics during the first wave of covid-19 in Tunisia.

3.2 Methodology

This paper aims to propose an interoperability index of the measures taken and adjusted by the Tunisian government during the first wave of coronavirus COVID-19. The concept of interoperability is defined in this research as the ability of measures, public policies or programs that have interests or objectives to be achieved, to operate together (see, for example, Ford et al.,2007; Ford, 2008; Novakouski and Lewis, 2012 and Rezaei, Chiew and Lee, 2014b).

We recall that the period between March 04th 2020 and June 13th 2020 (hereafter noted by S), corresponding to the entire first wave of the COVID-19 pandemic in Tunisia.

To identify the first wave of the COVID-19 pandemic in Tunisia whose interoperability is to be measured, we denote this period by $S = [P_1, P_2, \dots . P_T]$. where P_i, $i = 1, \dots \dots, T$ are the sub-periods that measures, pandemic policies are taken, added or modified.

Once the set of sub-periods has been identified, those sub-periods will be modeled using a set $X = \{M_1, M_2, M_3, \dots M_n\}$ which represent measures or decisions describing each sub-period.

These sub-period measures are represented by a set of measures states denoted $C = \{c_1, c_2, \dots c_n\}$, $c_i = [0, c_{max}]$. If M_i was not taken during the sub-period P_i then its state $c_i$is equal to 0, otherwise, it can take the value 1 if it was recommended or 2 when the application of this measure was mandatory. According to the dynamic governance (discussed above), the improvement of the decision-making process implies that if a measure is absent in P_i it does not necessary to be absent in P_{i+1}. Similarly, when the government assesses the non-usefulness of a measure it can relax it. Hence the state assigned to a measure may change overtime. Indeed, taking and announcing measures and policies is not enough to manage the pandemic situation and its consequences, a strictness in their application is needed as well. At this level, we will calculate an Index that records the strictness of government policies in each sub-period. This index is a simple average of the individual component indicators (measures) and it is described as follows:

$$\mathrm{I_{Stringency}\,(P_i)} = \frac{1}{\mathrm{k}} \sum_{\mathrm{j=1}}^{\mathrm{k}} 100 \times \frac{\mathrm{V_j}}{\mathrm{N_j}}$$

Where k is the number of component indicators, N_j the maximum state value of the measure (indicator) and V_j is the recorded policy value on the ordinal scale in the sub-period P_i.

On the other side, for each sub-period $P_i \in$ S characterized by a set of measures m $\subseteq$ X, we denote $\sigma_i = m(P_i) = \{M_1(P_i);\ M_2(P_i);\ M_3(P_i), \dots M_n(P_i)\}$, called the instantiation of P_i which models the P_i by the states of the measures in m.

Once all P_i have been instantiated, the sub-periods instantiations must be aligned with each other in order to support meaningful sub-period comparisons and to indicate how the measures taken / added or modified during a sub-period P_i operated with those taken, modified or added during the sub-period that follow. The alignment of the instantiation of the whole period S is given by the matrix $\sum = M(S) = \{\sigma_1;\ \sigma_2; \sigma_3; \sigma_4, \ldots\ldots \sigma_T\}$.

Based on the matrix $\sum$, we build a matrix of interoperability measurements for all sub-period pairs in S, using an interoperability function "$Interop$", for measuring the similarity of sub-periods instantiations and for giving a normalized measure of the period modeled by measures states.

The choice of interoperability function depends on the measure states with which the sub-periods are modeled. Two types of functions are present in the literature: The first type concerns modeling with binary-valued measures states (0 if the measure is absent and 1 if the measure is taken during the concerned sub-period). For this case, the appropriate interoperability function is given by:

$$\mathrm{Interop_{Bin}} = \frac{1}{n}\sum_{i=1}^{n}\left(\sigma'_{(i)} \wedge \sigma''_{(i)}\right)$$

where $\sigma', \sigma'' \in \{0,1\}^n$ and $\wedge$ is the Boolean AND operator.

The second type concerns the modeling of sub-periods with real-valued measure states $C = [0, c_{max}]$. In this case, the following function is recommended:

$$\mathrm{Interop_{Real}} = \mathrm{w.MMS} = \left[\frac{\sum_{i=1}^{n}\sigma'_{(i)} + \sum_{i=1}^{n}\sigma''_{(i)}}{2n.c_{max}}\right]\left[1 - \left(\frac{1}{\sqrt[r]{n}}\right)\left(\sum_{i=1}^{n} b_i \left(\frac{\sigma'_{(i)} - \sigma''_{(i)}}{c_{max}}\right)^r\right)^{1/r}\right]$$

$$b_i = \begin{cases} 0 & \text{if } \sigma'_{(i)} = 0 \text{ or } \sigma''_{(i)} = 0 \\ 1 & \text{else} \end{cases}$$

w is the mean value of the states characterizing two modeled sub-periods and MMS is the modified Minkowski similarity function. n is the number of measures used to model two sub-periods, c_{max} is the maximum value of measure states and r is the Minkowski parameter (usually set to r =2). $\mathrm{Interop_{Real}}$ has the capability of yielding very precise similarity measures of sub-periods instantiations limited only by the number of measures and the precision of those measures' states.

Given two sub-periods, P_i and $P_j \in S$ instantiated with σ_i,σ_j and an interoperability function "Interop", then, $m_{ij} = \text{Interop}(\sigma_i, \sigma_j)$ is the interoperability measurement of P_i and P_j. The interoperability matrix is given by $M = [m_{ij}]; i, j \leq |S|$ for all pairs of sub-periods (P_i, P_j).

$$M = \begin{array}{c} \\ P_1 \\ \vdots \\ P_T \end{array} \begin{array}{c} \begin{array}{ccc} P_1 & \dots & P_T \end{array} \\ \begin{bmatrix} 0 & \dots & m_{1T} \\ m_{ij} & 0 & \vdots \\ m_{ij} & \dots & 0 \end{bmatrix} \end{array}$$

In this research we assume that measures taken early in a sub-period interact directly with the next successive sub-period in the decision process, but they interact indirectly with every successive sub-period in the process because information they create or transform is eventually passed to successive sub-periods. No self-interoperability is assumed as well, so the diagonal of the interoperability matrix M will take a value of 0.

4. Empirical Results and Discussion

4.1 Responses Stringency, Duration and Change during the first wave of covid-19

Table 2 shows that the policy responses against covid-19 during the first wave in Tunisia have been changed from one sub-period to another. This change is observed in the new policy measures taken during each sub-period and in the adopted stringency level.

During the first sub-period P1, the Tunisian authorities chose just to recommend the cancellation of public events and imposed restrictions on international movement only with certain countries such as Italy, France and Egypt. At the same time, public officials began to urge caution against the new virus. In terms of health, the Tunisian strategy is based on testing all those carrying the symptoms of the virus and meeting specific criteria and on tracing the contacts of certain positive cases.

In fact, the testing policy did not change during the whole period of the first wave of the virus and including the second sub-period P2 which kept the same measurements taken in P1 but with different degrees of rigidity.

We note that the cancellation of public events has become mandatory after having been recommended in P1. Also, restrictions on international travel are imposed with all countries and the information campaign has become more intensive with a coordination between traditional and social media.

on the other hand, new measures and policies were taken during this second sub-period P2. For example, the closure of schools and universities has been imposed on all levels and categories. In addition, the closure of some workplaces was recommended or work for a few hours, in groups or with reduced capacity. people are urged to avoid large gatherings. Enforcement of this latest ruling has become mandatory during the P3, P4 and P5 sub-periods. During these sub-periods (P3, P4 and P5), the closure of workplaces became required for all activities except essentials. However, all other measurements taken in P1 and P2 were kept with the same levels of rigidity and inclusiveness of P2.

the new measures which came into effect from the P3 sub-period are the recommendation to reduce the volumes, routes of the main means of transport, the requirement not to leave the home except for necessities, the curfew, imposition of restrictions on internal movement and support workers in the informal sector, the poor and workers in the private sector who lost their wages and reduce debts and contracts for households.

all these measures were applied during the three sub-periods P3, P4 and P5 with the same level of rigidity and inclusiveness. However, we did see some changes during the P6 sub-period. First, the tracing strategy has become more inclusive by tracking all identified cases carrying the virus. Also, the resumption of activities in groups or with reduced capacity with the opening of workplaces for a few hours. As a result, the request to stay at home was recommended and not required as it was previously.

This gradual removal of restrictions contained during sub-period P7. as shown in the last column of table 2, the total removal of restrictions concerns internal movements, mass gatherings, events and public transport. In addition, workplaces, schools for certain levels and universities have become open with the application of health protocols appropriate to each sector. we noted that aid transfer and debt relief contained during P7 as well.

4.2 Sub-periods instantiations and Stringency index

The degree of interoperability between the Tunisian pandemic responses against covid-19 during the first wave is estimated using the sub-periods instantiations, which each sub-period is modeled by three coded states reflecting the dynamics of measures stringency and inclusiveness. the sub-periods instantiations are presented as follows:

$$\sigma_1 = m(P_1) = \{1; 1; 1; 1; 1; 0; 0; 0; 0; 0; 0; 0; 0\} \implies I_{Stringency}(P_1) = 12{,}5\%$$

$$\sigma_2 = m(P_2) = \{2; 2; 2; 1; 1; 2; 1; 1; 0; 0; 0; 0; 0\} \implies I_{Stringency}(P_2) = 50\%$$

$$\sigma_3 = m(P_3) = \{2; 2; 2; 1; 1; 2; 2; 2; 1; 2; 2; 1; 2\} \implies I_{Stringency}(P_3) = 93{,}75\%$$
$$\sigma_4 = m(P_4) = \{2; 2; 2; 1; 1; 2; 2; 2; 1; 2; 2; 1; 2\} \implies I_{Stringency}(P_4) = 93{,}75\%$$
$$\sigma_5 = m(P_5) = \{2; 2; 2; 1; 1; 2; 2; 2; 1; 2; 2; 1; 2\} \implies I_{Stringency}(P_5) = 93{,}75\%$$
$$\sigma_6 = m(P_6) = \{2; 2; 2; 1; 2; 2; 1; 2; 1; 1; 2; 1; 2\} \implies I_{Stringency}(P_6) = 81{,}25\%$$
$$\sigma_7 = m(P_7) = \{0; 2; 2; 1; 2; 1; 0; 0; 0; 0; 0; 1; 2\} \implies I_{Stringency}(P_7) = 18{,}75\%$$

These instantiations of the sub-periods were done using 13 main measures and policies taken by Tunisia to manage the first wave of the pandemic. The government policy stringency index is estimated directly from sub-periods instantiations using the measures M_1, M_2, M_6, M_7, M_8, M_9, M_{10} and M_{11} (Table 2).

Between 04 and 12 March, only five measures were implemented to control the circulation of the virus on Tunisian territory, they represent 38% of all political responses taken during the first wave of covid-19 in Tunisia. The degree of rigor of these measures is low and it is estimated at 12.5% during the P1 sub-period.

On March 13, 2020, Tunisia officially entered epidemiological phase 3. This development forced the Tunisian authorities to add three new measures and also to increase the level of stringency of P1 measures. we estimated the degree of rigor during P2 by 50%. However, this change did not last long (a one week), then Tunisia entered full containment and five additional measures were added from March 22. During the P3 sub-period, the level of stringency of government pandemic responses reached its estimated maximum of 93.75%. with such a maximum level, Tunisia managed the two sub-periods P4 and P5.

With such a maximum level of rigor, Tunisia has managed the two sub-periods P4 and P5 as well. the presence of 13 measures applied with a maximum stringency level led to a remarkable stability of the epidemiological situation in the country whose number of new cases per day fell to 10 cases on average during P5 after having been around an average of 30 cases in P3 and P4.

This stability was translated by a reduction in the level of policy stringency which decreased to 81.25% in P6 and it fell to 18.75% during the P7 sub-period keeping only 53.8% of measurements that were present during P5 and P6.

Pandemics and crisis, as we mentioned above, cannot be managed or defeated with one single measure or policy even through a highest stringency level. they are managed with several policy responses which inter-react together overtime to achieve the objective.

4.3 Pandemic Policies Interoperability Analysis

In this section we present firstly the degrees of interoperability between the measures taken or adjusted during two successive sub-periods, then we present the interoperability matrix of all sub-periods' pairs. Given the variation of the pandemic response states between 0 and 2, our estimates are based on modified Minkowski similarity function and are presented as follows:

$$m_{12} = Interop\ (\sigma_1; \sigma_2) = \frac{5+12}{2 \times 13 \times 2}\left[1 - \frac{1}{\sqrt[2]{13}}\left(\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+1+\frac{1}{4}+\frac{1}{4}\right)^{\frac{1}{2}}\right]$$

$$\mathrm{m}_{12} = \mathrm{Interop}\ (\sigma_1; \sigma_2) = \ 0.327 \times 0.583 = 0.190$$

$$\mathrm{m}_{23} = \mathrm{Interop}\ (\sigma_2; \sigma_3) = \ 0.654 \times 0.446 = 0.291$$

$$\mathrm{m}_{34} = \mathrm{Interop}\ (\sigma_3; \sigma_4) = \ 0.846 \times 1 \quad = 0.846$$

$$\mathrm{m}_{45} = \mathrm{Interop}\ (\sigma_4; \sigma_5) = \ 0.846 \times 1 \quad = 0.846$$

$$\mathrm{m}_{56} = \mathrm{Interop}\ (\sigma_5; \sigma_6) = \ 0.827 \times 0.76 \ = 0.628$$

$$\mathrm{m}_{67} = \mathrm{Interop}\ (\sigma_6; \sigma_7) = \ 0.615 \times 0.444 \ = 0.273$$

the degree of interoperability between the measurements of P1 and P2 is estimated by m12 = 0.190. This low interrogability between the two sub-periods P1 and P2 is mainly due to the number of measurements added in P2 and also to the modification of the degree of rigidity of

measurements taken in P1. In other words, this low degree of interoperability reflects the weak reaction of the Tunisian public decision-maker to the evolution of the epidemiological situation. this reaction was relatively improved in P3 with the addition of new measures with a maximum level of stringency. Consequently, the degree of interoperability between P2 and P3 estimated by m23 = 0.291 has also increased. Indeed, the number of measurements and their level of rigidity did not change during P4 and P5 which led to estimate the same degree of interoperability by m34 = m45 = 0.846 between P3 and P4 on the one hand and between P4 and P5 on the other hand. such degree is highest during the whole period and is explained by the prolongation of total confinement twice in P4 and P5. By switching to targeted confinement, the rigidity of certain measurements has been relaxed and the degree of interoperability between P5 and P6 is estimated by m56 = 0.628. This decrease is mainly due to the modifications made to measure M10 representing the demand to stay at home and which became recommended

after having been required and to measure M7 with the partial opening of workplaces while reinforcing the tracing strategy of contacts of which all identified cases become concerned.

During the P7 sub-period, the measures M1, M7, M8, M9, M10 and M11 were removed and the measure M6 was lightened. all these modifications in terms of management led us to estimate an interoperability index between P7 and P6 by m76 = 0.273. on the other hand, the interoperability between the measures taken or modified over time during the first wave is estimated using the following interoperability matrix:

$$\begin{bmatrix} P_i & P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 \\ P_1 & 0.000 & 0.190 & 0.130 & 0.130 & 0.130 & 0.160 & 0.172 \\ P_2 & 0.190 & 0.000 & 0.291 & 0.291 & 0.291 & 0.317 & 0.153 \\ P_3 & 0.130 & 0.291 & 0.000 & 0.846 & 0.846 & 0.628 & 0.212 \\ P_4 & 0.130 & 0.291 & 0.846 & 0.000 & 0.846 & 0.628 & 0.212 \\ P_5 & 0.130 & 0.291 & 0.846 & 0.846 & 0.000 & 0.628 & 0.212 \\ P_6 & 0.160 & 0.317 & 0.628 & 0.628 & 0.628 & 0.000 & 0.273 \\ P_7 & 0.172 & 0.153 & 0.212 & 0.212 & 0.212 & 0.273 & 0.000 \end{bmatrix}$$

From this matrix, there is evidence that measures taken early in a sub-period interact directly with the next successive sub-period in the decision process, but they interact indirectly with every successive sub-period in the process because information they create or transform is eventually passed to successive sub-periods. such a matrix could help to understand the evolution of managerial behavior of Tunisian public decision maker over time by observing the measures taken at each sub-period and their stringency degrees.

5. Conclusion

In this paper, we have analyzed the interoperability of measures taken by the Tunisian government to manage the first wave of the Covid-19 pandemic. The first wave of covid-19 outbreak in Tunisia was lasted almost three and a half months. it was started since the discovery of the first case in March 02, 2020 and it was extended until June 13, 2020 date of total control of the health situation, where zero new confirmed cases recorded during several successive days. The pandemic policies that we have documented in this research are classified by their implemented dates. Such responses classification allowed us to break down the first wave period into seven successive sub-periods. Then, we have modeled each sub-period using by three coded states reflecting the dynamics of measures in terms of their stringency and inclusiveness. The results obtained show that the process of making decision during the first wave in Tunisia is described as a revised and adjusted process in continuous upgrading, which policy responses have been changed from one sub-period to another. This change is observed

in the new policy measures taken during each sub-period and in the adopted stringency level. By estimating the stringency index, we found that, as of March 23, the level of stringency of government responses to the pandemic reached its estimated maximum of 93.75%. With such a maximum level of rigor, Tunisia also managed the two sub-periods where total containment was extended two times. Consequently, the presence of 13 measures applied with a maximum level of rigor led to a remarkable stability of the epidemiological situation in the country whose number of new cases per day fell to 10 cases on average during the second extension of confinement after have been around an average of 30 cases at the start of the lockdown sub-period. This stability resulted in a reduction in the level of policy stringency which decreased to 81.25% during the targeted containment and it fell to 18.75% during the total deconfinement sub-period characterized by the end and the relaxing of several policies implemented previously. On the other hand, after estimating the interoperability index, we found that the measures taken early in a sub-period interact directly with the next successive sub-period in the decision process, but they interact indirectly with other successive sub-periods. Furthermore, there is clear evidence that Pandemic crisis cannot be managed or defeated with one single measure or policy even through a highest stringency level. but it was managed with several policy responses which inter-react together overtime.

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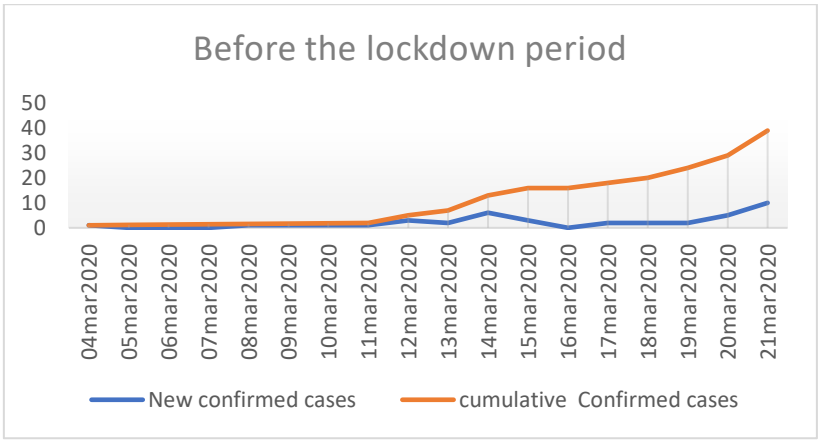
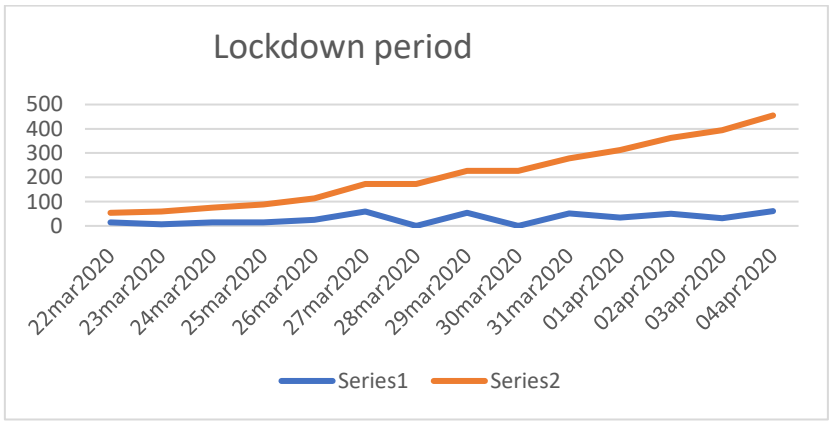
Appendix


Before the lockdown period
50
40
30
20
10
0
04mar2020
05mar2020
06mar2020
07mar2020
08mar2020
09mar2020
10mar2020
11mar2020
12mar2020
13mar2020
14mar2020
15mar2020
16mar2020
17mar2020
18mar2020
19mar2020
20mar2020
21mar2020
New confirmed cases
cumulative Confirmed cases


Lockdown period
500
400
300
200
100
0
22mar2020
23mar2020
24mar2020
25mar2020
26mar2020
27mar2020
28mar2020
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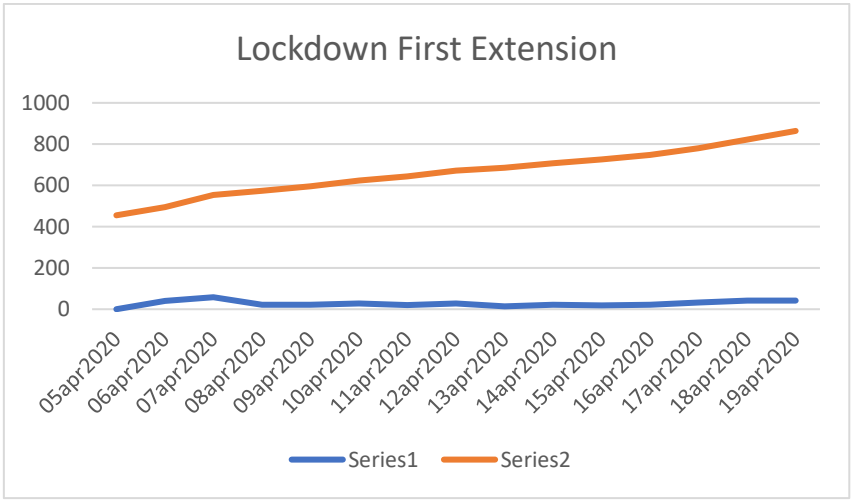
01apr2020
02apr2020
03apr2020
04apr2020
Series1
Series2


Lockdown First Extension
1000
800
600
400
200
0
05apr2020
06apr2020
07apr2020
08apr2020
09apr2020
10apr2020
11apr2020
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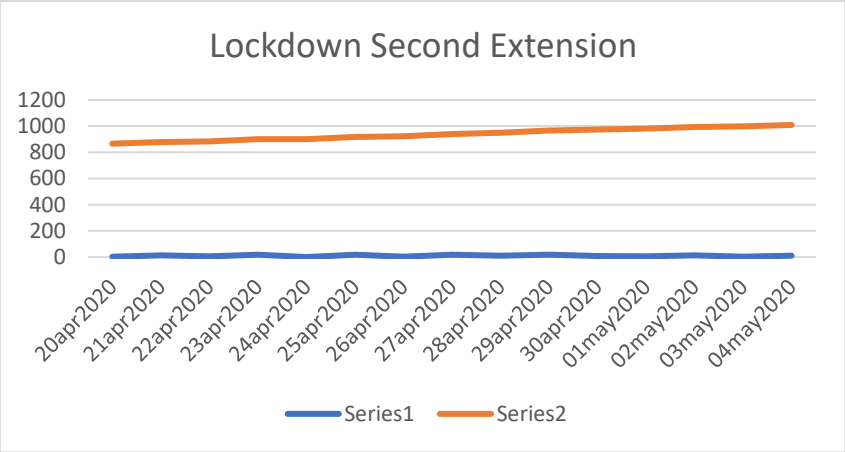
17apr2020
18apr2020
19apr2020
Series1
Series2


Lockdown Second Extension
1200
1000
800
600
400
200
0
20apr2020
21apr2020
22apr2020
23apr2020
24apr2020
25apr2020
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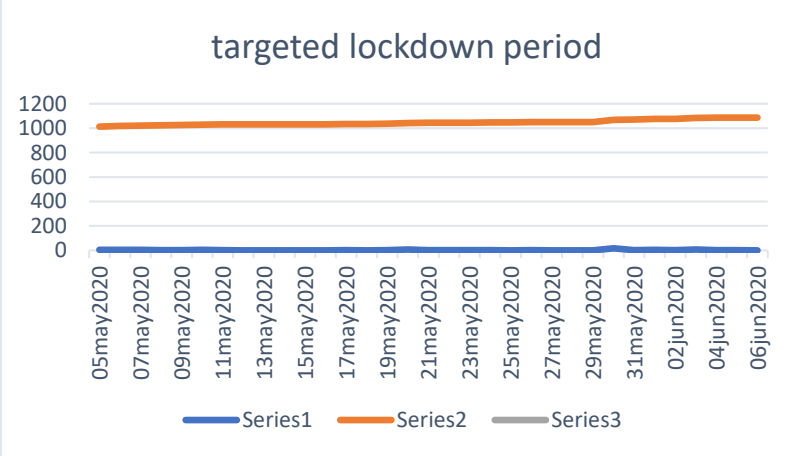
04may2020
Series1
Series2


targeted lockdown period
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1000
800
600
400
200
0
05may2020
07may2020
09may2020
11may2020
13may2020
15may2020
17may2020
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02jun2020
04jun2020
06jun2020
Series1
Series2
Series3

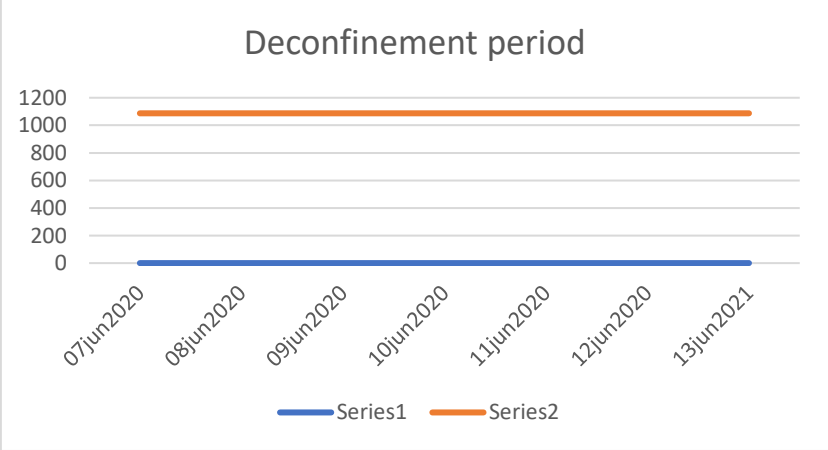
Deconfinement period
1200
1000
800
600
400
200
0
07jun2020
08jun2020
09jun2020
10jun2020
11jun2020
12jun2020
13jun2021
Series1
Series2

Table 2: Policy Responses, Coding and Change during the first wave of covid-19

Policy responses	Coding / States	Sub-periods						
		P1	P2	P3	P4	P5	P6	P7
M_1: Cancel Public events	0- No measures 1- Recommend cancelling 2- Require cancelling	√	√	√	√	√	√	√
M_2: Restriction on international travel	0- No restrictions 1- Restrictions on one or more countries, but not all countries. 2- Restrictions on all countries	√	√	√	√	√	√	√
M_3: Public information campaign	0- No covid-19 public information campaign 1- Public officials urging caution about-covid-19 2- Coordinated public information campaign across traditional and social media and intensification.	√	√	√	√	√	√	√
M_4: Testing Policy	0- No testing policy 1- Testing those who have symptoms or meet specific criteria 2- Open public testing	√	√	√	√	√	√	√
M_5: Contact tracing	0- No Contact tracing 1- Contact tracing not done for all cases 2- Contact tracing done for all identified cases	√	√	√	√	√	√	√
M_6: School closing	0- No measures 1- Recommend closing schools for some levels 2- Require closing schools for all levels and categories	√	√	√	√	√	√	√
M_7: Workplace closing	0- No measures 1- Recommend closing or work from home or restricted opening hours/ groups or not all capacity for some businesses and government activities	√	√	√	√	√	√	√

	2- Require closing for all-but keeping essential workplaces (grocer0y stores, doctors...)							
M_8: Restrictions on gatherings	0- No measures 1- Recommend avoiding large gatherings 2- Require restriction on gatherings	√	√	√	√	√	√	√
M_9: Public transport closing	0- No measures 1- Recommend significantly reduce volume/ route/ means of transport available 2- Require closing public transport	√	√	√	√	√	√	√
M_{10}: Stay at home requirements	0- No measures 1- Recommend not leaving house 2- Require not leaving house with exception for daily exercise, grocery shopping and essential trips	√	√	√	√	√	√	√
M_{11}: Restriction on internal movement	0- No measures 1- Recommend not to travel between region cites 2- Internal movement restrictions in place and curfew applied	√	√	√	√	√	√	√
M_{12}: Income support	0- No measures 1- Government transfers support to informal workers, poor and private formal workers who lost salary 2- Government transfers support to informal workers, poor and public and private formal workers who lost salary	√	√	√	√	√	√	√
M13: Debt/ contract relief	0- No debt/contract relief 1- Narrow relief, specific to one kind of contract 2- Broad debt/contract relief	√	√	√	√	√	√	√

√: indicates the measure (policy) states during each sub-period